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Most scientists have little time or reason these days to be concerned with the history of the scientific literature. This is understandable since scientific and technical developments are occurring so rapidly that no one working in experimental science can afford to dissipate energy looking back too far or too long. Such activity must be reserved for the historian. But, because this year is the 300th anniversary of the founding of the scientific periodical, I thought it of interest to review certain historical events associated with this interesting subject. Before continuing, I wish to indicate that various aspects of this topic have been discussed extensively by others (1, 2, 3, 8, 11, 12).

We do not know the precise date of the first scientific report. Early civilizations of China, India, Egypt, Assyria, and Babylonia contributed to science and technology in several ways. But writings from such civilizations are difficult to evaluate since only fragments remain of many ancient herbals, papyri, and cuneiform clay tablets. In ancient Greece, the communication of scientific knowledge was largely oral, because of the scarcity of written scrolls.

Successful printing from movable type by Gutenberg about 1455 was highly significant in the dissemination of knowledge. This event was a prerequisite to the wide circulation of scholarly writing, because it provided for the first time multiple copies of manuscripts in the form of books.

Owing to intellectual, economic, social, and technological advances in the 16th and 17th centuries, a literate and leisured class arose in Europe. During these times "natural philosophers" began to advocate the scientific method of inquiry and the direct observation of nature. Francis Bacon, for example, felt scholars were placing too much emphasis on fixed ideas, and he recognized the need of "minds washed clear of prejudices and preconceptions" when he said:

"We are not to imagine or to suppose,

but to *discover*, what nature does or may be made to do"; and "Read not to contradict and confute, nor to believe and take for granted . . . but to weigh and consider."

René Descartes went even further in discarding teachings transmitted from the ancient world. He recommended "the methodic doubt of everything . . . and to start again with thyself asking questions and looking for explanations that can be proved." People with intellectual curiosity were intrigued by this concept, and other similar teachings, and they began to devote their leisure time to the critical examination of ideas. Scholars soon realized, however, that the *search for truth* was not merely a superficial term, but rather an actual experience in life. As a result, they sharpened their powers of observation and began to experiment extensively on nature. Such activity stimulated the development of science, and this immediately led to the problem of exchanging new scientific knowledge.

At the beginning of the 17th century, written scientific communication was primarily through books and gazettes. Soon there arose in science, however, this important formula: one experiment or observation equals one communication or publication. This formula was of significance because it meant that current methods of publication were inadequate. The characteristic book was inappropriate for presenting the results of one new experiment or observation, because an author had to wait until he accumulated several results before he could justify publication. Even so, many single observations or discoveries continued to be published in the form of separate booklets or pamphlets. William Harvey's great work on the circulation of blood, for example, appeared as a 72-page booklet in 1628. The early gazettes or newspapers consisted mainly of reports from so-called intelligence offices, and they were not suitable for transmitting scientific information.

Because Bacon and others advocated that the experimental method could best be promoted by the corporate action of natural philosophers,

¹ Presidential address delivered in Washington, D.C., on 5 May 1964, at the Annual Meeting of the American Society for Microbiology.

frequent informal and sometimes secret meetings of men of science were held between 1600 and 1650 in various centers of Europe. These assemblies (sometimes referred to as the "invisible college") were soon to lead to the founding of many great scientific academies and societies. The results of the experiments and discussions, and the other events of philosophical and political importance in the early meetings, were frequently recorded. Copies of the records were then sent as letters to friends engaged in similar activities in other centers. Communication in all countries at that time was facilitated by Latin, the international language of the learned. But the vernacular was also coming into use by natural philosophers.

By 1660 the men of science recognized that they were dependent on private correspondence to keep abreast of the new knowledge being discovered throughout the world. Many invitations were extended among inquisitive colleagues to exchange ideas through letters. For example, the first letter book of The Royal Society contains a letter dated 22 July 1661 by the president, Sir Robert Moray (14), who was writing De Monmort in Paris about the scientific method and the interchange of scientific information. This interesting letter (Fig. 1) describes so exactly the situation of science in the middle 17th century that it is worthy of reading by all persons interested in the history of science; a translation of the letter follows:

"Most excellent sir,

Some days ago that most accomplished man, our Tullius, was telling us with what honor and liberality he had been received in your famous assembly; this news has so touched our Society that, although we believe your welcome to have been paid (and deservedly) to his notable excellence, yet it is not difficult to see in it also, quite plainly, your good wishes towards ourselves. Especially, when he added further with what concern you heard him discourse on the methods and institutions of our Society. For he told us that you earnestly rejoiced that studies had been undertaken by men . . . who should revive the examination of nature, through so many centuries past neglected and lying fallow, and who should translate such

examination into the sphere of everyday life. Nay more! he said that your Society strongly desired (and for some time now it has been well versed in such things) that there should be communication among us of whatever knowledge may further for posterity these most necessary of studies.

We embrace in the place of highest honor what is surely the work of a most sublime humanity, work handed down to us of their own accord by most illustrious men. Indeed, being ourselves engaged in this pursuit, we freely confess that we have felt an added spur from your example; such that your land of France must be admitted, if not to have rendered the whole of philosophy from the roots upward more healthy, then certainly to have adorned it most greatly in recent years, and to have expanded it. To bear witness to the truth of this fact, it is not now necessary that we should bring up those great names, Descartes and (Garsendum), who seem to have come to a study of philosophy through some natural genius, and whose method of philosophy . . . they did not find written out in . . . sterile and infertile treatises of our ancestors, but which they dug out of the things of nature for themselves; whose method . . . we value highly; moreover when it sometimes happens that the greatest men find themselves in difficulties, or even, as it turns out, blocked completely, it is just this method which must be promoted (study the things of nature themselves). For it will never allow us to proceed always in the wrong direction, and amid great mists of obscurity. For this reason, we who hope to finish some part of this long journey, it is certain that first of all we must construct the necessary plan of experiments, experiments which may bring light to our errors, redeem us if we go continually wrong, and ease the difficulties of the way. In our attempt to describe the true nature of a thing, which up till now philosophy seems to have lacked . . . an inquiry into the correct arrangements of nature, or with

seeking out sound experiments, on which . . . the whole bulk of the future work may rest.

deservedly said to be the first to restore to our day and age the rule of wisdom of the ancients, which wished no one

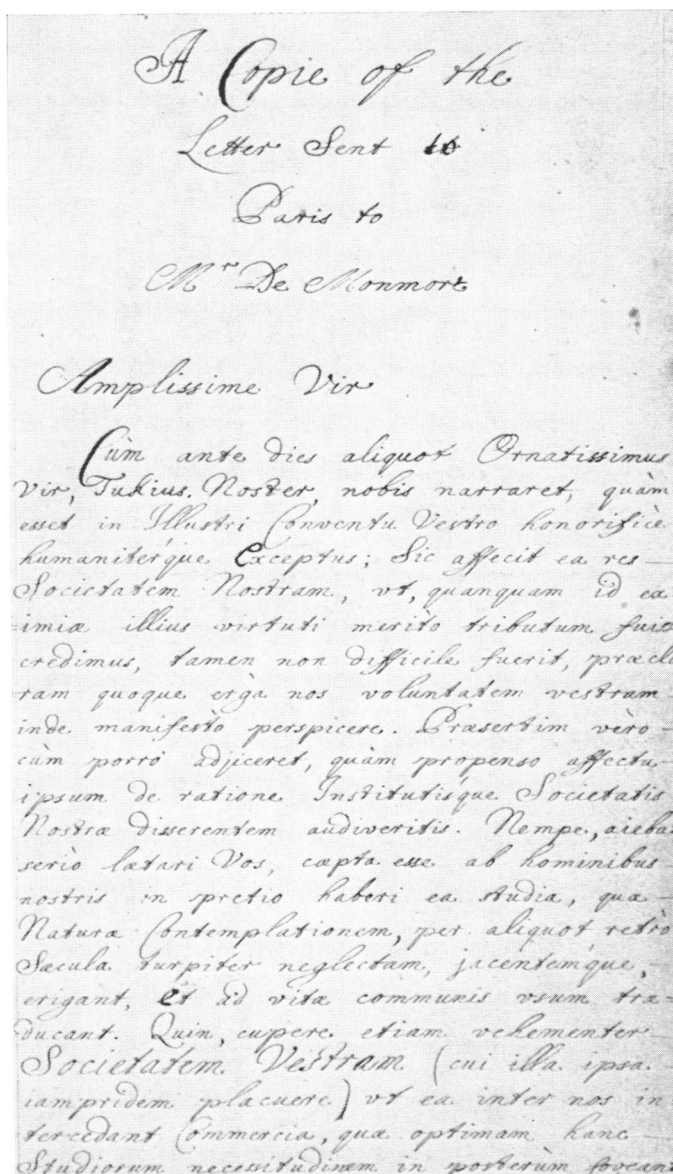


FIG. 1. Copy of letter from Sir Robert Moray to M. de Monmort, 22 July 1661. Reproduced by permission of the Royal Society.

"May I, indeed, say this in addition? Little by little those who study philosophy seem to be learning from that most famous method of great Galileo, who so joined geometry to philosophy that he is

'unskilled in geometry'² to be initiated into their rites. You will say the work

² Refers to the legend that Plato forbade entrance to his Academy to anyone without a knowledge of geometry [mathematics], causing this

Qua sane exquisita humanitatis officia,
nobis à Clarissimis Viris vltis delata.
Summi honoris loco amplectimur. Enimvero
& Nobis in hoc Adagio currentibus, ad-
exemplo vestro Calcar vltis addi libenter
fatemur; ut adeo Gallia vestra si non
omnem sonorem Philosophiam à fundo
mentis constituisse, certe tamen illam
Nuperis annis exornasse plurimum, atque
ampliasse dicenda sit. Non jam necesse est,
magna illa Nomina, Cartesium atque Gu-
sendum, in hujus rei fidem producamus,
qui peculiari quidam Genio ad eam trac-
tandam accessisse videntur: Quorum Phi-
losophandi rationem non quidem è Majorum
Commentarijs, sterilibus plerumque, & in-
fructuosis, Descriptam, sed è rebus ipsis
erutam, magni; et ipse est, estimamus: Si-
ubi autem Viris Maximis aut haerere al-
quando, aut etiam, ut fit, capitate, conti-
gerit, dandum id profecto humanitati, cui
nunquam in hac obscura rerum caligine ra-
tione semper pede progredi licebit. Nobis
idcirco, qui partem aliquam longinqui huius
Itineris conficere speramus, certum est in-
primis necessarium experimentorum com-
munitatem instruere, qua & lucem errantibus
accendant, & offensantes continuis suble-
vent & via molestias diluant. Namque, ut
quid res est dicamus, id unum hactenus
Philosophia defuisse videtur, quod non-
satis se exerceuerint homines in Historiæ
Naturæ rite adornandæ, conquistendisque
bonæ fidei experimentis, quibus, ceu firmis
maxima subtractioni tota futuri operis molis
innectatur

FIG. 1. Continued

is altogether hard, and frightening in its
immensity alone! And so it is, most
renowned Monmort; it is a work that
will easily exhaust the efforts of all the

inscription to be displayed: [translation from
Greek] "Let no one without a knowledge of geom-
etry enter."

centuries. For this reason we ask the
more confidently for your helping hand,
Meanwhile, continue in your philo-
sophical studies, most celebrated men,
and you in special, most excellent Mon-
prepared in our turn, should our labor
in anything be of advantage to you, to
make available to your good will our

own resources, whatever they may be. mort, and while you receive Philosophy and the Muses with hospitality a grate-

Robert Moray found that his correspondence required much time and energy. In a letter of 27 August 1661 to Christian Huygens in Holland,

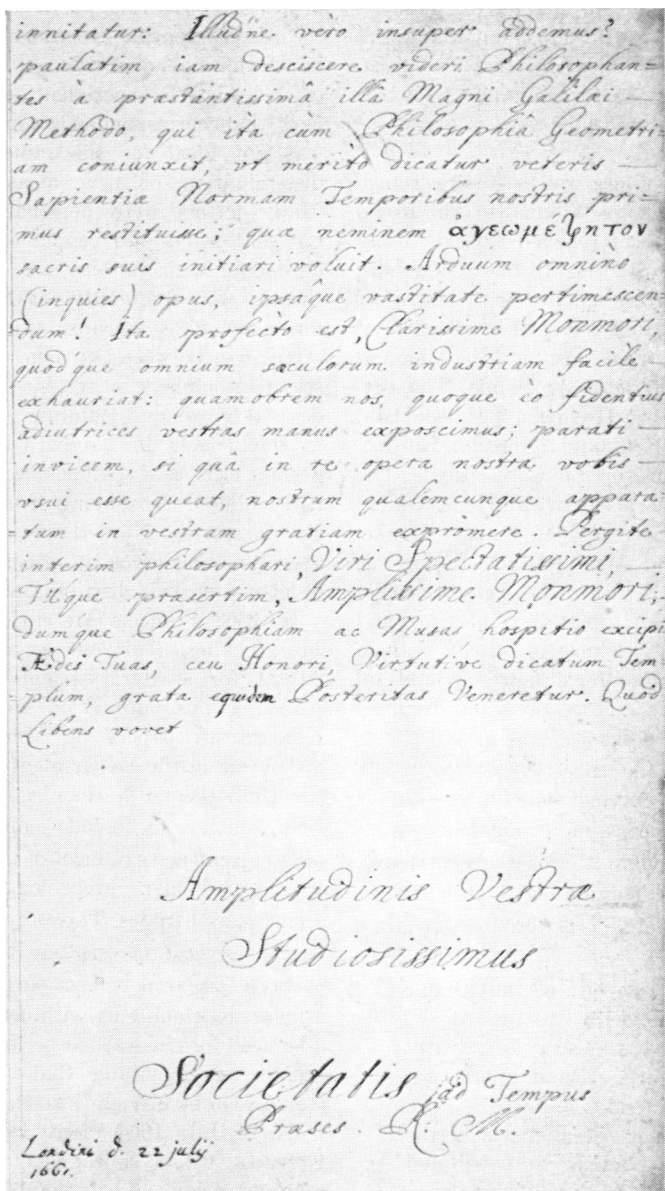


FIG. 1. Continued

ful posterity will reserve your house as a temple dedicated to honor and to virtue . . .” [Translated by Stanley Johnson, University of Iowa]

he (15) expressed the need of some aid in his work. At the same time, he may have been introducing the idea of a journal when he said (Fig. 2):

“It will be impossible for me to inform

you, by letter, of all the particulars that have occurred. But I believe from time to time we shall print what passes among ourselves, at least everything that may be published. Then you shall have copies among the first, and if there is something withheld from publication, it will be much easier for me to communicate it to you, than to send you word of everything by letters."

When Henry Oldenburg was elected Secretary (jointly at first with John Wilkins) to The Royal Society in April 1663, he relieved Robert Moray of much of his letter writing. In fact, Oldenburg began extensive correspondence with the most philosophical and curious persons in all parts of the world. He was continuously writing long and detailed letters to at least 30 people. The persons overseas included Huygens, Leeuwenhoek, Leibnitz, Malpighi, Redi, and Spinoza in Europe, and Governor Winthrop of Connecticut. The foremost English scientists with whom Oldenburg corresponded were Boyle, Halley, Hooke, Lister, Newton, and Wren. In describing his duties, Oldenburg (6, 16) wrote that his correspondence "employs a great deal of time and [that he] takes great pains to satisfy foreign demands about philosophical matters, [and to] disperse far and near . . . directions and inquiries for the Society's purpose . . ."

Within the year the work became so heavy that Oldenburg also needed assistance with his foreign correspondence, and arrangements were made to establish a committee for correspondence. In August 1664, Oldenburg (17) wrote Robert Boyle, who was living in Oxford at the time (Fig. 3):

"On Friday last our committee for correspondence met the first time at Mr. Povey's where we were sorry to be without you, and without your queries for Guinea . . . General inquiries were drawn up, serving for all parts of the world, and authors were distributed among the members of the committee, to be perused for the collecting thence particular inquiries for particular countries. This was our entertainment above ground: I leave you to guess what our correspondence and entertainment was underground in the grotto, and near . . .

so many dozens of wine bottles of all kinds."

Communication by letter writing simplified the spelling and form of many words and phrases in use at that time, and the letters provided records of scientific experiments. But just as the book was inadequate for publishing the results of one scientific experiment, so it was soon realized that correspondence among small groups was not ideal for the rapid and widespread dissemination of new ideas and knowledge. Many letters were personal, and they were not sent usually to people who would criticize or debate their contents. As a result, unsound theories were frequently not disputed or rejected for some time. Because questions of priority often arose between two men, or among groups of scientists, ciphers or systems of shorthand were devised by some to maintain secrecy. The answer to the defects in handwritten correspondence became clear to several people. The printing press had rendered the making of books in quantity a simple matter. Now these same presses could save time and labor by printing multiple copies of letters for wide distribution.

In 1663 Francois Mézeray, historian to the French king, took out a privilege or letters patent for a literary-scientific periodical; the plans for this publication are described in the handwritten papers of Mézeray (13), which are on file in the Department of Manuscripts of the Bibliothèque Nationale. Mézeray's publication was not to include political records, but only current news in most of the fields of interest to cultured men: archeology, arts, literature, sciences, and trades. This project was never realized for several reasons, but it did mark the first concrete proposal in Europe for a device to aid scholars in keeping up with new scientific events. The need for the learned periodical was at hand, and it was inevitable that such a publication would soon be brought into existence.

On 26 July 1664 Pierre Perrier (Marquis de Crenan) (18), a colleague of the great French mathematician and philosopher Pascal, wrote the following postscript on a letter to Huygens in Holland (Fig. 4):

"M. de Sallo, Counselor of the Court of Parliament, desires to have correspondence throughout Europe in order to learn of new events, as much as in

affairs of State as in matters of science. He has asked me to write you requesting your approval for an exchange of news to this end; he is a person of merit, and of consideration."

formed extensive anthologies, and arranged the material so he could find quickly information on any desired subject. He conceived the idea that by publishing his material he might do for the public what he was doing for himself. The

A Monsieur
Monsieur Christian Huygens
de Zolichem
X¹¹ La Haye.
A Whitehall ce 27. Aou. 1661.

ACAD.
Monsieur DE SAT.
BIBL.

Je m'excuse
impossible de vous informer, par lettre, de toutes les particularités
de nos nos nouvelles. Mais je crois que de temps en temps
vous m'écrirez, ce qui pourra m'être utile, en me les envoyant
par le port. Alors vous m'enverrez toujours des copies des
promises. et si il y a quelque chose de nouveau qu'on ne me
faisait savoir, je me ferois alors beaucoup facile à vous le
communiquer, que de vous faire participer de tout par lettre.

Monsieur
Vre très humble et très obéissant
serviteur
Robert Moray

FIG. 2. Parts of a letter from Sir Robert Moray in London to Christian Huygens at The Hague, 27 August 1661. Reproduced by permission of Department of Western Manuscripts, Bibliotheek der Rijksuniversiteit te Leiden.

This statement concerned a proposed project by Sallo to collect material for a new type of publication. Sallo was an unusual and ingenious person. He belonged to the group of learned men of the time who were thoroughly in sympathy with dispelling superstition and intolerance. He kept two scribes or copyists working constantly, transcribing the most remarkable passages he encountered in his reading. He

scheme to publish a weekly journal was submitted to Colbert, the controller-general of finances under Louis XIV. Colbert and others hailed the idea as unique and encouraged the project.

On 8 August 1664 a privilege was signed for *Le journal des sçavans* (Journal of Learned Men) at Fontainebleau, and this was followed by the announcement of the publication in various

circles throughout Europe. Sallo's privilege (21) was registered 30 December 1664 and it reads as follows (Fig. 5):

"Today a privilege has been presented to us, obtained by Sir Denis de Sallo,

The first weekly issue of the *Journal* was published 5 January 1665 (Fig. 6); it consisted of 20 pages, and it contained ten articles, letters, and notes. The purpose of the *Journal* was well stated in the address of the printer to the reader

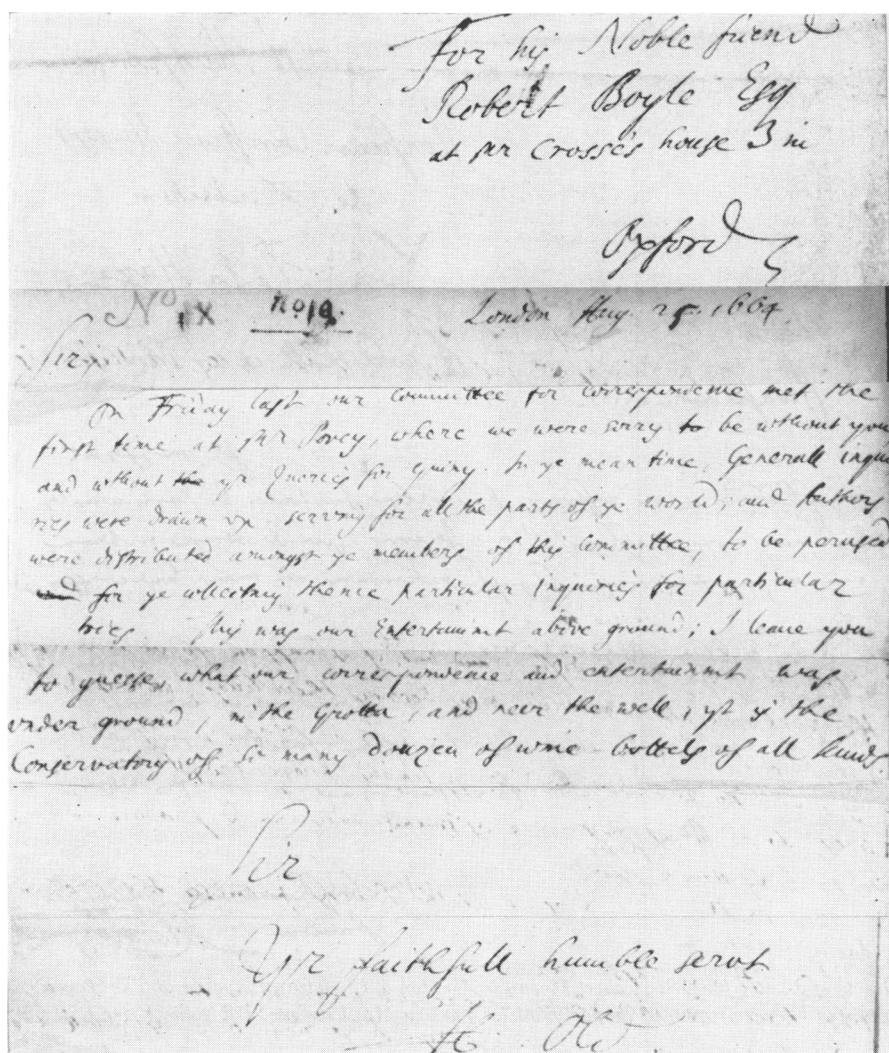


FIG. 3. Parts of a letter from Henry Oldenburg in London to Robert Boyle in Oxford, 25 August 1664. Reproduced by permission of the Royal Society.

Counselor in the Court of Parliament, for the printing of the *Journal des Sçavans*: granted for twenty years; dated from 8 August 1664 and signed by Pecquot: The above privilege was handed over by Sir De Sallo to Jean Cusson, Bookseller, by today's act."

in the first issue (Fig. 7). It proposed (i) to catalogue and to give useful information on books published in Europe; (ii) to print necrologies of famous persons and summarize their works; (iii) and, most significant for us, to make known experiments in physics, chemistry, and anatomy that may serve to explain natural phenomena, to

describe useful or curious inventions of machines, and to record meteorological data; (iv) to cite the principal decisions of civil and religious courts and censures of universities; and finally (v) to transmit to readers all current events worthy of the curiosity of men.

Sallo retained his right to the publication of the *Journal* under the assumed name of de

grew in popularity throughout Europe. The impression it made on the public at the time may be gained by citing parts of a letter (preserved as a copy at the University of Leiden) from Emeric Bigot (5) of Rouen to the Dutch philologist Nicolaas Heinsius (Fig. 8):

"At the beginning of this year, a new sort of Gazette began to be printed,

Le 26^e Juillet 1664
à Paris

Monsieur De Sallo Bon^{or} de la Cour de Parlement. Je vous prie de
m'excuser de vous ennuier par ces lettres, mais je suis si curieux
des choses qui se passent tant de pays, & de tant d'affaires
d'estat que celui qui me regarde les sciences & l'histoire de
vous écrire pour vous prier de m'en dire un peu
comme aux autres, sur cela, c'est une personne de
merite, et de consideration,

FIG. 4. Footnote of a letter from P. Perrier in Paris to Christian Huygens at The Hague, 26 July 1664. Reproduced by permission of Department of Western Manuscripts, Bibliotheek der Rijksuniversiteit te Leiden.

M^r de Sallo
à M^r Cuffey.

Du 30. Decembre 1664.

Considérant que vous avez présenté les Brevets obtenus par le Sieur Denis de
Sallo, Conseiller de la Cour de Parlement pour l'impression du Journal des Sçavans;
Amis de vous être un; & dact^e du 8. d'Avril 1664. & Signé Riquart: Ledit Brevet
n'est pas mentionné dans le Sieur de Sallo à M^r Cuffey d'obtenir par acte de nomination.

FIG. 5. Privilege for Sallo to print *Le journal des sçavans*, 30 December 1664. Reproduced by permission of Bibliothèque Nationale.

Hedouville. According to several historians, this was the name of a small piece of land that Sallo owned in Normandy; but, according to others, it was the name of his servant, who was also called Germain (22).

Sallo claimed that the "*Journal* was invented for the relief of those either too indolent or too occupied to read whole books" and that "It is a means of satisfying curiosity and becoming learned with little trouble." Several of Sallo's friends helped review and edit the new *Journal*, and they spent much time discussing natural philosophy as they worked. This new periodical

published every week in Paris, and is entitled *Le journal des sçavans* . . ."

[After eight pages of extracts from the reports in the *Journal*, Bigot continues.]

"You see that I . . . sent you . . . something . . . that I thought you might like to know about. If these kinds of journals are not reprinted in Holland, or are not sent to you from somewhere else, I shall make similar extracts if you wish. Perhaps there will be found sometimes some notes to be added that the author of the journal does not dare to

print He calls himself Mr. Roussel de Hedouville. I have written to Paris to know whence he comes, what his

months (13 numbers), because of the severe criticism, the *Journal* was suppressed, and Sallo's privilege was withdrawn. Publication was soon

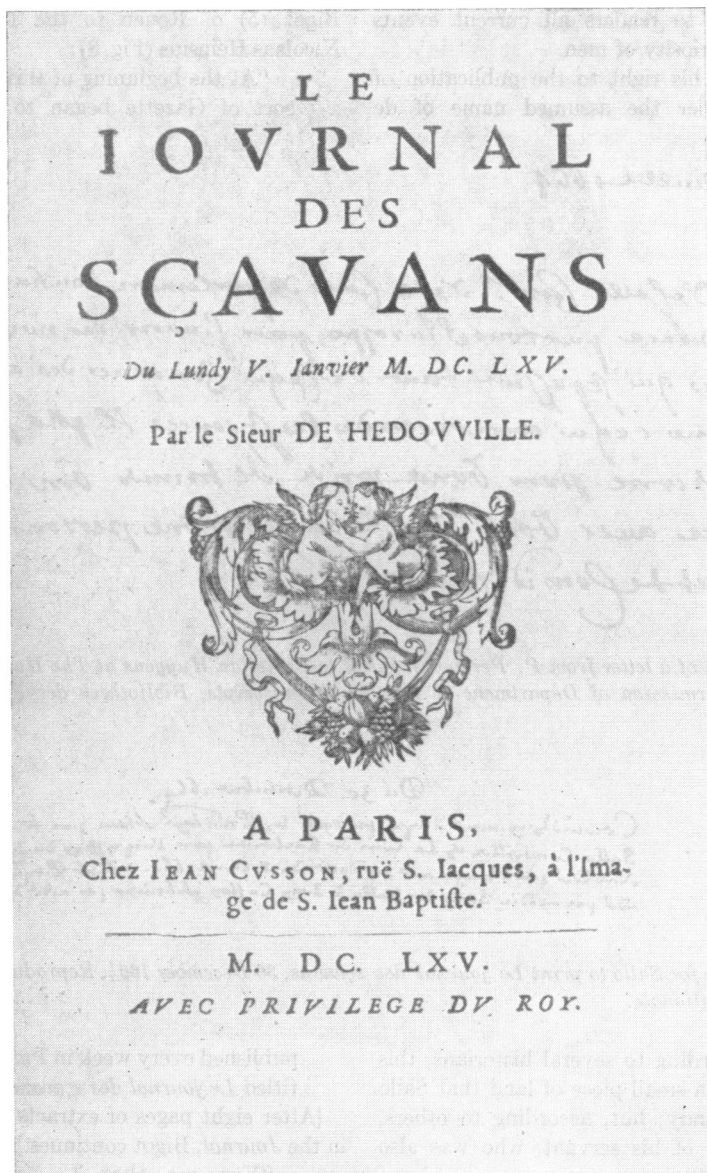


FIG. 6. Title page of first issue of *Le journal des sçavans*. Reproduced by permission of Harvard University Library.

profession is, and what he does in Paris; when I find out I will let you know."

The more popular the *Journal* became with the general public, the more it was censored without discretion by the authorities. After 3

resumed (4 January 1666) under the direction of l'Abbe Gallois, one of Sallo's collaborators. Reprint editions were also published for awhile in Holland (1665-1792) and in Germany (1667-1671). After several irregular periods of publica-

tion during the next 150 years, the *Journal* was reorganized in 1816 (as *Journal des Savants*); it continues today as one of the leading literary journals in Europe.

accounts of experiments conducted before the Society. Finally, the Council of The Royal Society (20) ordered on 1 March 1664–5 (Fig. 9): "... that the *Philosophical Transactions*, to be

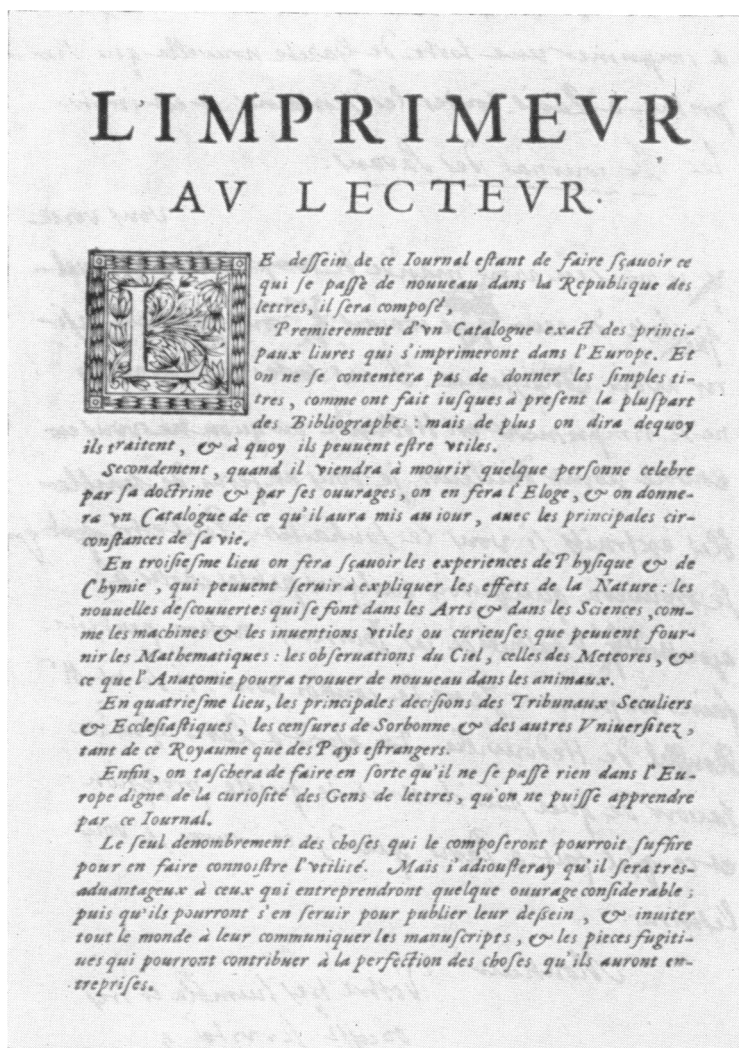


FIG. 7. Page (*L'imprimeur au lecteur*) from *Le journal des sçavans*, which explains the purpose of the publication. Reproduced by permission of the Harvard University Library.

At the time *Le journal des sçavans* was being established in France, plans were underway in England to publish a somewhat different type of periodical. Moray, Boyle, Hooke, Oldenburg, and others discussed this matter for some time. They concluded that a more truly scientific periodical was needed, excluding legal and theological matters, but including especially the

composed by Mr. Oldenburg, be printed the first Monday of every month, if he has sufficient matter for it, and that the Tract be licensed by the Council of the Society, being first reviewed by some of the members of the same"

In conformity with this order the first issue of the *Transactions* appeared on Monday, 6 March 1665 (Fig. 10). It consisted of 16 pages, and it

Ce 10 february 1665

Monsieur

Au commencement^{ent} de cette année on a ^{commencé} à imprimer une sorte de gazete nouvelle qui s'imprime à Paris. toutes les semaines et est intitulée Le journal des Savans.

vous voiez

je vous en avois mandé de temps en temps quelque chose. de ceux ~~que~~ je croiois ~~que~~ vous pourriez désirer avoir ^{connoissance}. Si ces sortes de journaux ne se n'impriment en Hollande ou qu'on ne vous en envoie point d'ailleurs, je vous en ferai de semblables extraits si vous le souhaitez. Peut être ~~qu'il~~ qu'il se trouvera quelquefois quelques petites choses à ajouter. L'Auteur de ces journaux n'osera peut être faire imprimer. Je ne le connois point. il se dit M^r. Roussel de Hedouville. J'ai écrit à Paris afin de savoir de quel pais il est et de quelle profession et ce qu'il fait à Paris, quand je le saurai je vous l'écrirai.

Monsieur

Votre très humble et très
obéissant serviteur
Bigot B

FIG. 8. Parts of a letter from Emeric Bigot in Rouen to Nicolaas Heinsius in Holland, 10 February 1665. Reproduced by permission of Department of Western Manuscripts, Bibliotheek der Rijksuniversiteit te Leiden.

contained a dedication to The Royal Society, an introduction, nine articles, and a listing of certain important philosophical books (Fig. 11). At first the direction, composition, and publication of the *Transactions* were entrusted to Mr. Oldenburg; not until the 47th volume in 1753 did this

serial become the official publication of The Royal Society. This great publication has survived for 300 years, with only a short period (1676-1683) of dormancy. During this time its volumes have contained some of the most illustrious scientific papers published anywhere.

But in the early years the *Transactions* faced many perils.

Because plague was prevalent in London during 1664–1665 there was a great exodus of people from the city. This severely handicapped all forms of business, and especially the sale of the *Transactions*, which did not cater to the interests of a widespread public audience. Further problems arose when the Great London Fire swept

and Holland. This mission was accomplished. Soon after arriving in London, Oldenburg became a close friend of Milton, Pepys, and other distinguished scholars of the day. Because of certain events, he began to devote himself to the “new experimental learning” with the cherished “belief that the world was not too old or the living race too exhausted to bring forth something new.” After he became Secretary to The Royal Society

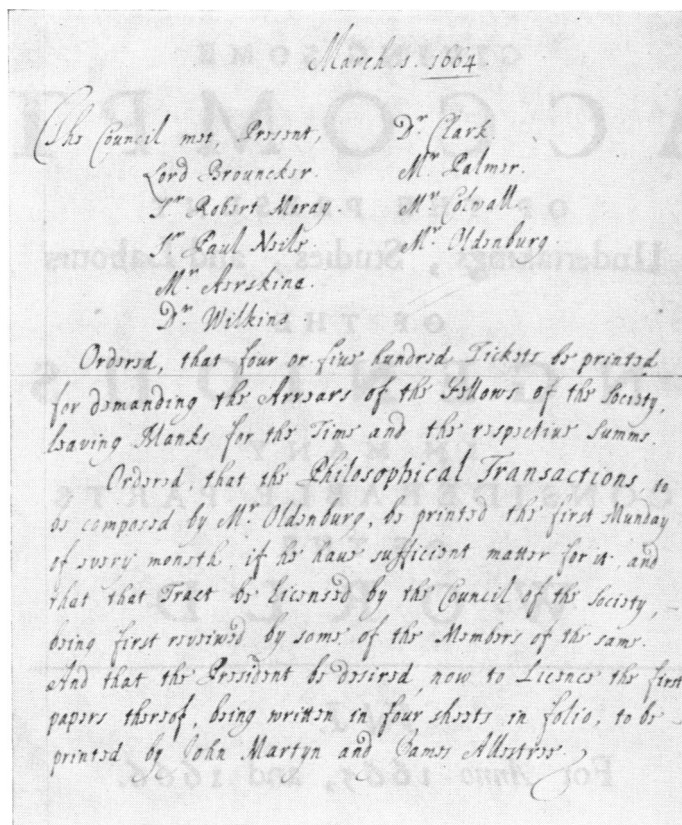


FIG. 9. Minutes of the Council meeting (1 March 1664) of the Royal Society ordering the first printing of the *Philosophical Transactions*. Reproduced by permission of the Royal Society.

the city in September 1666, destroying back issues of the *Transactions* in storage at stationers.

Before moving on, I wish to speak briefly about and pay respects to Henry Oldenburg (Fig. 12), the first editor of a truly scientific journal (16). Oldenburg, who sometimes signed his name anagrammatically as *Grubendol*, was a theologian, statesman and diplomat, man of letters, and a natural philosopher. He went to London from Bremen in 1653 to negotiate a treaty with Cromwell in the war between England

he donated so much time to the organization that he encountered difficulty earning a good living, and he suffered many hardships. When the Council of the Society authorized him to publish the *Transactions* in 1664, it was intended that revenue from sales would pay for his gratuitous services. But the net profit never amounted to more than 40 pounds a year. Because of his extensive foreign correspondence during the trade war with the Dutch he excited suspicion of the English court, and for awhile he was im-

prisoned in the Tower of London. His latter days were embittered by a disagreement with his colleague, Robert Hooke, who complained because the *Transactions* had not done justice to his invention of the hairspring for pocket watches.

first to appear was a scientific journal in Germany, the *Acta eruditorum*; it was published in Latin at Leipzig in 1682, and it continued for many years. The *Acta* will be remembered for many papers by Leibnitz on calculus, and by

**PHILOSOPHICAL
TRANSACTIONS:
GIVING SOME
ACCOMPT
OF THE PRESENT
Undertakings , Studies , and Labours
OF THE
INGENIOUS
IN MANY
CONSIDERABLE PARTS
OF THE
WORLD.**

Vol I.

For *Anno* 1665, and 1666.

In the SAVOY,
Printed by T. N. for John Martyn at the Bell, a little without Temple-Bar , and James Allestry in Duck-Lane ;
Printers to the Royal Society.

FIG. 10. Title page of the first issue of *Philosophical Transactions*. Reproduced by permission of the Library of Congress.

Oldenburg's *Transactions* and Sallo's *Journal* served as two distinct models for all subsequent scientific periodicals. The *Transactions* became the standard for publications of academies and societies that promoted experimental science throughout the world. For example, one of the

Leeuwenhoek on microbiology. The *Journal des sçavans* was imitated by serials that appealed to audiences with broad interests in literature, theology, law, history, and philosophy. One of the first of these, *Giornale de' Letterati d' Italia*, was published in Rome from 1668 to

1697. By the end of the 17th century, about 30 scientific and medical periodicals had been established. But most of these were short lived.

Several of these journals continue today. Periodicals devoted specifically to microbiology did not appear until 1887, when both the *Annals de*

(1) Numb. 1.

PHILOSOPHICAL TRANSACTIONS.

Munday, March 6. 1664.

The Contents.

An Introduction to this Treatise. An Account of the Improvement of Optick Glasses at Rome. Of the Observation made in England, of a Spot in one of the Belts of the Planet Jupiter. Of the motion of the late Comet predicted. The Heads of many New Observations and Experiments, in order to an Experimental History of Cold; together with some Thermometrical Discourses and Experiments. A Relation of a very odd Monstrous Calf. Of a peculiar Lead-Ore in Germany, very useful for Essays. Of an Hungarian Bolus, of the same effect with the Bolus Armenus. Of the New American Whaling about the Bermudas. A Narrative concerning the success of the Pendulum-watches at Sea for the Longitudes; and the Grant of a Patent thereupon. A Catalogue of the Philosophical Books published by Monsieur de Fermat, Counsellour at Tholoufe, lately dead.

The Introduction.



Hereas there is nothing more necessary for promoting the improvement of Philosophical Matters, than the communicating to such, as apply their Studies and Endeavours that way, such things as are discovered or put in practise by others; it is therefore thought fit to employ the *Press*, as the most proper way to gratifie those, whose engagement in such Studies, and delight in the advancement of Learning and profitable Discoveries, doth entitle them to the knowledge of what this Kingdom, or other parts of the World, do, from time to time, afford, as well

A

of

FIG. 11. Contents, introduction, and first article in the *Philosophical Transactions*. Reproduced by permission of the Library of Congress.

The early journals did not contain many papers describing the results of original experiments as we know them. Today's characteristic form of the scientific paper appeared about 1780–1790, with the publication of specialized journals in physics, chemistry, biology, agriculture, and medicine.

l'Institut Pasteur and *Centralblatt für Bakteriologie und Parasitenkunde* began publication.

According to Prutz (19), the first authentic abstracting journal appeared in 1714 "to provide the learned with literary treasures hidden in the latest issues of 40 periodicals." This secondary

(2)

of the progress of the Studies, Labours, and attempts of the Curious and learned in things of this kind, as of their compleat Discoveries and performances: To the end, that such Productions being clearly and truly communicated, desires after solid and usefull knowledge may be further entertained, Ingenious Endeavours and Undertakings cherished, and those, addicted to and conversant in such matters, may be invited and encouraged to search, try, and find out new things, impart their knowledge to one another, and contribute what they can to the Grand design of improving Natural knowledge, and perfecting all *Philosophical Arts, and Sciences*. All for the Glory of God, the Honour and Advantage of these Kingdoms, and the Universal Good of Mankind.

An Account of the improvement of Optick Glasses.

There came lately from *Paris* a Relation, concerning the Improvement of *Optick Glasses*, not long since attempted at *Rome* by Signor *Giuseppe Campani*, and by him discoursed of, in a Book, Entituled, *Ragguaglio di nuoue Osservationi*, lately printed in the said City, but not yet transmitted into these parts; wherein these following particulars, according to the Intelligence, which was sent hither, are contained.

The *First* regardeth the excellency of the long *Telescopes*, made by the said *Campani*, who pretends to have found a way to work great *Optick Glasses* with a Turne-tool, without any Mould: And whereas hitherto it hath been found by Experience, that *small Glasses* are in proportion better to see with, upon the Earth, than the *great ones*; that Author affirms, that his are equally good for the Earth, and for making Observations in the Heavens. Besides, he useth three Eye-Glasses for his great *Telescopes*, without finding any *Iris*, or such *Rain-bow colours*, as do usually appear in ordinary Glasses, and prove an impediment to Observations.

The *Second*, concerns the *Circle of Saturn*, in which he hath observed nothing, but what confirms Monsieur *Christian Huygens de Zulichem* his Systeme of that Planet, published by that worthy Gentleman in the year, 1659.

FIG. 11. *Continued*

serial was discontinued after 3 years. But by 1830 over 300 primary journals were being published, and abstracting journals were revived. By comparison, this year *Biological Abstracts* alone will cover 6,000 primary journals and report more than 105,000 abstracts.

I do not wish to tire those of you who are filled with the wonders of the present with further

details about journals of the past. Rather, I want to bring you up to date quickly by indicating that, beginning with 1665 and continuing until today, the growth of scientific periodicals has been exponential, with the number of primary journals doubling every 18 to 20 years. Estimates on the number of scientific and technical serial journals in the world today range from 25,000

to 100,000. The most reliable study on this subject, by Gottschalk and Desmond (9), shows 35,300 current periodicals (Table 1). To this number, however, may be added approximately 8,000 technical reports of government and

culture, 18% to medicine, and 16% to the natural and physical sciences (Table 2).

A conservative estimate indicates that 15,000 journals in the world contain material of biological interest. This includes 4,000 agricultural



FIG. 12. Henry Oldenburg (1615?–1677), first editor of a truly scientific journal. From a portrait by Johannes van Cleef. Reproduced by permission of the Royal Society.

commerce, and 9,000 to 11,000 house organs and related publications which usually do not contain material of primary nature. The scientific and technical literature of the world is published currently in over 60 languages.

In the six countries publishing the largest number of journals, approximately 48% of the serials are devoted to technology, 18% to agri-

and 4,000 medical serials, and approximately 7,000 journals in pure biology. Studies by Miles Conrad (7) at *Biological Abstracts* indicate that, if the exponential rate of growth of journals continues until the year 2000, we may expect that year to have about 60,000 periodicals of biological significance.

The average number of articles per year in a

TABLE 1. Number* of current scientific and technical serials published in 1961 (from Gottschalk and Desmond, 1963)

Country	No.
Africa (continent)	650
Australia	450
Austria	500
Belgium	1,250
Bulgaria	150
Canada	550
China (People's Republic)	650
China (Republic)	200
Czechoslovakia	400
Denmark	400
Finland	300
France	2,800
Germany (East and West)	3,050
Greece	50
Hungary	250
India	650
Indonesia	100
Ireland	50
Italy	1,500
Japan	2,800
Korea (Democratic People's Republic)	50
Korea (Republic)	100
Latin America (Caribbean area, Central and South America, Mexico)	2,650
Netherlands	650
New Zealand	150
Norway	250
Pakistan	100
Philippines	100
Poland	750
Portugal	250
Rumania	150
Spain	300
Sweden	700
Switzerland	800
Thailand	50
Turkey	100
U.S.S.R.	2,200
United Kingdom	2,200
United States	6,200
Yugoslavia	400
Other countries	400
Total	35,300†

* Figures have been rounded off to the nearest 50. Those countries which published fewer than 50 journals have been grouped together under "Other countries."

† Error estimated as $\pm 10\%$ due to the incompleteness of listings checked, and undetermined mortality rates.

biological journal is approximately 50. This means that currently about 750,000 articles are published in the world each year, for an average of 85 articles per hour. If the present pace continues until 2000, this number may rise to 3 million biological articles, or a production of over 320 per hour. No one can now comprehend the staggering amount of information so many articles may contain.

Supposedly, there are about 3 million scientists and technologists in the world today (at least we know there are approximately 1 million in the United States). Estimates are that this number will increase 10 to 15 times by the end of the century. But if it now takes 35,000 periodicals to provide publication outlets for 3 million scientists and technologists, then it is conceivable that ten times as many workers may require 350,000 journals. It is futile to estimate the number of articles, or the new information, appearing in a third of a million journals. How can scientists, librarians, and others cope with this tremendous increase in the scientific literature?

Studies indicate that the average scientist reads with comprehension at a speed of 200 to 300 words a minute. Reading as slowly as he does in his own field, the scientist can hardly make a dent on his "required reading" these days, to say nothing about future requirements if we think in terms of one-third million journals. As a result, scientists are looking forward to mechanized help from indexing (24), abstracting, and translating machines (10), or from other electronic devices (4, 23).

It is possible that electronic computers will soon be able to translate rapidly, word for word. They may be able to spell correctly similar words such as bacterium and bacteria, *Penicillium* and penicillin, and viral and virus. They may be capable of associating in a sentence the subject, verb, and object by working through logical progression. Certainly, various types of electronic apparatus will meet great needs if they can both translate and abstract, thereby delivering bundles of facts from the difficult foreign languages. But such machines cannot be considered to have even a trace of imagination, curiosity, originality, initiative, or skepticism—a few of the characteristics of a good scientist. Just as a computer blinks lights of frustration when a technician tries to divide infinity by zero, so will abstracting and translating machines be dumbfounded when

confronted with the appraisal or interpretation of new scientific facts or jargon. The view that machines will think as a creative man does reveals a misunderstanding of the nature of human thought. The most important instrument in good research is, and always will be, the mind of man. And there can be no communication of scientific and technical information by man without some form of comprehension and understanding by other human beings.

Soon, we hope, somebody will perfect and make

and may suffocate from its own immense production. I challenge each of you to ponder the formidable and perplexing difficulties associated with communicating and comprehending the scientific literature.

With ingenious thinking and vigorous, sustained effort we can surely design methods of communication that will, in the words written three centuries ago by Robert Moray (14), "... bring light to our errors . . . , and ease the difficulties of the way."

TABLE 2. *Percentage of serial publications devoted to broad subjects in six countries (from Gottschalk and Desmond, 1963)*

Subject	France	Germany	Japan	UK	USA	USSR
	%	%	%	%	%	%
Technology.....	49	44	45	45	56	49
Agriculture.....	18	16	23	22	23	16
Medicine.....	21	21	18	13	13	12
Natural and physical sciences.....	12	19	14	20	8	23

available at reasonable cost an apparatus similar to Vanavar Bush's MEMEX (MEMORY extender), or Homer W. Smith's ELICADUS (electron library instantaneous catalog and deliver us service). Such apparatus will deliver microfilms or one to several thousand microcards on a given topic within a few seconds after a button is pushed. But an "electronic brain" that can read, digest, and use information on microfilms or cards seems extremely remote to most of us. For some time to come, I am sure, mere men and women with relatively weak and fallible brains must still do these tasks. We can all help lighten the load, however, by avoiding the development of a "distinctive lingo" for each branch of science—especially, a lingo that is incomprehensible to people in other disciplines. Precise numbers and equations can be used to explain many things in the physical sciences. But the use of absolute expressions to describe most events in the biological world is impossible. Thus, clear and concise statements are essential in the explanation of biological phenomena.

We have reached a period in science somewhat similar to that encountered by our colleagues of 300 years ago. Creative and inventive minds must now discover new methods for coping with the scientific literature. If this is not done, science will face a real crisis within a generation

LITERATURE CITED

1. ANDRADE, E. N. da C. 1949. The presentation of scientific information. *Proc. Roy. Soc. (London) Ser. B* **136**:317-333.
2. BARNES, S. B. 1934. The beginnings of learned journalism, 1665-1730. Ph.D. Thesis, Cornell University, Ithaca, N.Y.
3. BARNES, S. B. 1934. The scientific journal, 1665-1730. *Sci. Monthly* **38**:257-260.
4. BELLO, F. 1960. How to cope with information. *Fortune* **62**(3):162-167, 180, 182, 187, 189, 192.
5. BIGOT, E. 1665. Letter to Nicolaas Heinsius, 10 February, Bermann manuscripts Q18, f. 103. *Bibliotheek der Rijksuniversiteit te Leiden*, Department of Western Manuscripts.
6. Birch Manuscript, British Museum, 4441, f. 27. *See also* Oldenburg, H. (16).
7. CONRAD, G. M. 1961. A philosophic approach to the problems of communication. *Biol. Abstr.* **36**(7):XX-XXII.
8. GARRISON, F. H. 1934. The medical and scientific periodicals of the 17th and 18th centuries. With a revised catalogue and check list. *Bull. Inst. Hist. Med.* **2**:285-343.
9. GOTTSCHALK, C. M., AND W. F. DESMOND. 1963. Worldwide census of scientific and technical serials. *Am. Doc.* **14**:188-194.
10. KING, G. W., AND HSIEN-WU CHANG. 1963. Machine translation of Chinese. *Sci. Am.* **208**(6):124-135.

11. KRONICK, D. A. 1962. A history of scientific and technical periodicals. The origins and development of the scientific and technical press 1665-1790. The Scarecrow Press, Inc., New York.
12. MCKIE, D. 1948. The scientific periodical from 1665 to 1798. *Phil. Mag. Comm.*, p. 122-132.
13. MÉZERAY, F. E. de. 1663. Privilège de Mézeray. Bibliothèque Nationale, Département des Manuscrits. *Papiers de Mézeray*: Ms. fr. 20792, au milieu du volume après la lettre N. Deux feuillets contenant le projet de Mézeray avec des corrections de sa main. *See also*, essay on De Mézeray by St. Beuve in *Cauceries du Lundi* VIII; cited by Barnes, S. B. (2).
14. MORAY, R. 1661. A copy of the letter sent to Paris to M. de Monmort, 22 July. Royal Society (London), Letter Book One, p. 1-3.
15. MORAY, R. 1661. Letter to Christian Huygens, 27 August 1661. *Oeuvres complètes de Christian Huygens (Correspondence 1661)* 3:317-318 (No. 886). Manuscript from Bibliotheek der Rijksuniversiteit te Leiden, Department of Western Manuscripts.
16. OLDENBURG, H. (1615?-1677). *Dictionary of National Biography* 42:94-96.
17. OLDENBURG, H. 1664. Letter to Robert Boyle. Boyle Works 6:149-151. Royal Society (London), Early Letters O.B. 26, p. 4.
18. PERRIER, P. (MARQUIS de CRENAN). 1664. Letter to Christian Huygens, 26 July 1664. *Oeuvres complètes de Christian Huygens (Correspondence 1664)* 5:90-92 (No. 1246). Manuscript from Bibliotheek der Rijksuniversiteit te Leiden, Department of Western Manuscripts.
19. PRUTZ, R. E. 1845. *Geschichte des deutschen Journalismus*, p. 43-44. C. F. Rius, Hannover.
20. ROYAL SOCIETY (London). 1664. Council Minutes 1, p. 90.
21. SALLO, D. de. 1664. Enregistrement du privilège Sallo. Bibliothèque Nationale, Département des manuscrits. *Archives de la Chambre syndicale des libraires et imprimeurs de Paris*. Ms. fr. 21945. *Registre des privilèges*. fol. 36 v°.
22. SALLO, D. de. 1825. *Biographie universelle, ancienne et moderne* 40:189-192.
23. U.S. LIBRARY OF CONGRESS. 1963. *Automation and the library of congress*. U.S. Government Printing Office, Washington, D.C.
24. U.S. PUBLIC HEALTH SERVICE. 1963. *The MEDLARS story at the National Library of Medicine*. U.S. Department of Health, Education, and Welfare, Washington, D.C.